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Oboe Transparency Results – Oboes 1-9

R.A. Heinle

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OBOE TRANSPARENCY RESULTS – OBOES 1-9

by

R. A. Heinle
October 15, 2002

Introduction and Motivation

The motivation for the "Transparency" experiment is that DOE/DP would like to have data available to show to interested parties, such as the JASONs. The U1a subcritical experiments are consistent with U.S. policy on nuclear testing. This would be done in a spirit of "Transparency" if doubts should arise. Thus, the objective of the "Transparency" measurements on the Oboe series is to place an upper bound on the nuclear energy released in the subcritical experiments.

Two separate experimental packages cover the transparency measurement issue thoroughly. These are:

1. Neutron Track-Etch Dosimetry.
2. Scintillator Fission Neutron/Gamma Rate Measurement.

Fig. 1. Transparency detectors on Oboe Barrier.

Because the containment barrier is only 1-inch steel, plus 6-inch shotcrete, it is quite transparent to fission neutrons and, thus, both experiments can be mounted outside the containment barrier and can be recovered post shot. An additional group of dosimeters was placed on the lid of the vessel for greater sensitivity.

We describe briefly the results of both of the experiments below. Fig. 1 shows a photo of the containment barrier and one of the dosimeter arrays and the Scintillator measurement. Fig. 2 shows each experiment location on the containment barrier. Fig. 3 shows a photo of a dosimeter array placed on the lid of the vessel. For a complete description of each experiment, please see the Oboe Subcritical Experiment Pre-Operational Report (UCRL-ID-135569).

Sensitivity Calculations

To determine the *in situ* sensitivity of the track etch dosimeters and the Scintillator Fission Neutron/Gamma Rate Measurement, a Monte-Carlo simulation of the problem was set up and run with the COG code.[i]

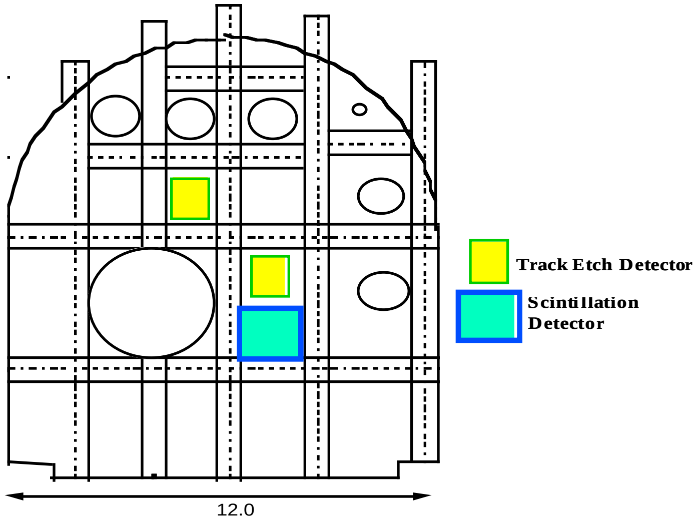

Fig. 2. The Oboe Barrier.

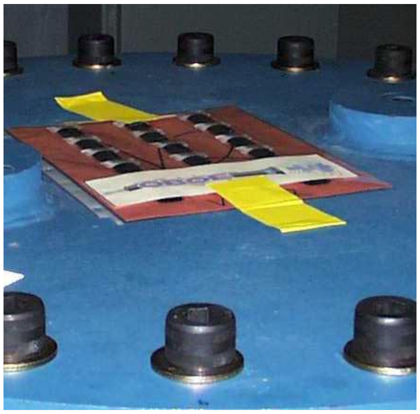

Fig. 3. Dosimeters on vessel lid.

A simulated device source was placed in the extreme rear of the zero room that we modeled, about 16 m away from the barrier. The probability of neutrons and photons, from the source crossing the barrier, were computed. The appropriate detector response functions[ii] were included for the active PM detectors and the dosimeters. A summary of those calculations is shown below in Table 1.

Table 1. Transparency Calculations.

	Neutrons	γ–MeV
Fissions/1 gram energy release	1.40E+14 fissions	
n source for 1 gram energy release at outer sfc of HE	3.04E+14	
γ Source for 1 gram energy release at outer sfc of HE		7.25E+13
Barrier Transmission	1.64E-01	4.49E-01
Detector Response	6.64E-02	7.28E-01
Detector Area	232 cm^2	
Solid angle (based on 1582 cm distance)	7.37676E-06 ster	
Active Detector		
Neutron Flux into detector/g TNT energy release	3.68E+08 neutrons	
Gamma Flux into detector/g TNT energy release	2.40E+08 γ-MeV	
Track Etch Dosimeters		
Barrier Expected track value for 1 gram "device"	140.53 tracks/(cm^2-gram TNT)	
Lid Expected track value for 1 gram "device"	2.44E+05 tracks/(cm^2-gram TNT)	

Neutron Track-Etch Dosimeter

The neutron track-etch dosimeter measurements are simple and electronics free. These involve standard integrated neutron dosimetry using CR-39 track-etch detectors outside the containment barrier and on the vessel lid. For each SCE, four 8-1/2 x 11” cards, each containing 16 dosimeters, are placed on the left rib of the 102 drift, on the center of the containment barrier, on the left side of the barrier, and on the lid of the vessel. The dosimeters are placed before firing and recovered when the zero room is re-entered.

Upon recovery, the sample cards are retrieved, the dosimeters are removed from the cards and placed in bags. These bags are delivered to Bechtel Nevada Dosimetry, who processes the data and returns the results to LLNL several weeks later. These dosimeters are processed “blind.” BN does not know which dosimeter was at what location. BN then emails LLNL the results back in the form of spreadsheets. We sort the results by actual location and analyze the data using a calibration value obtained by averaging all of the BN calibrations for each run on each SCE in the series.

The number of tracks/foil and the variance is computed by simple averaging from the sorted BN data. Then, the value for L_C, the decision level, is computed for the 99.9% confidence level on a per foil basis.

Here we used the fact that $L_C = t_{.001}\sqrt{(2.*B)}$ where $t_{.001}$ is the “student’s t” distribution for the 99.9% confidence level, based on a large sample size, with B being the variance.[iii] The values computed for L_C in counts/foil are then extended to each array of 16 foils by dividing the appropriate sensitivity values and $\sqrt{16}$ to apply the fact that we have 16 dosimeters on each card station (Currie). Similarly, we add in quadrature the results from the two cards of dosimeters that were on the containment barrier for the event. A summary of the “Transparency” dosimeter results from each SCE is included at the end of this section in Tables 2-10.

Oboe 9 was treated somewhat differently. Bechtel Nevada stopped analyzing the dosimeter data themselves and contracted with an outside organization (ICN Corporation) to provide the dosimeters and the post-collection analysis. ICN was unable to provide track density, but rather supplied dose in mrem per dosimeter directly. Aside from this, the dosimeters were treated the same statistically.

Table 11 summarizes the dosimeter results from each of the segments in the Oboe series. To help understand Table 11, we look at Oboe 1. On Oboe 1, for the 32 foils on the Oboe Containment Barrier, we get an average of 4.8 tracks/foil, compared to an average background of 5.6 tracks/foil. We are 99.9% certain that we had no energy release above 0.08 grams TNT; such a release would have required an average track value greater than 8.97 tracks.

For the 16 foils on the Oboe 1 Vessel, we get an average of 5.9 tracks/foil compared to an average background of 5.6 tracks/foil. We are 99.9% certain that we had no energy release above 0.08 mg TNT; such a release would have required an average track value greater than 9.89 tracks.

Table 2. Oboe 1 Summary.

OBOE 1 SUMMARY

	102 Drift R Group	Center of Barrier B Group	Right side of barrier C Group	Vessel V Group
Pre Event Average/foil	4.75 tracks	7.40 tracks	5.13 tracks	5.417 tracks
Variance	4.93 $(tracks)^2$	8.65 $(tracks)^2$	4.38 $(tracks)^2$	4.85 $(tracks)^2$
99.9% DL/foil	9.74 tracks	12.89 tracks	9.18 tracks	9.65 tracks
Level threshold for 16 foils	0.130 grams-TNT	0.172 grams-TNT	0.123 grams-TNT	0.001 grams-TNT

For all 32 foils on the Oboe 1 Containment barrier we get:

Event Average/foil	5.24 tracks	4.759 tracks	4.787 tracks	5.934 tracks
Variance on 32 foils	4.96 $(tracks)^2$	3.752 $(tracks)^2$	4.65 $(tracks)^2$	5.091 $(tracks)^2$
99.9% DL/foil	9.76 tracks	8.49 tracks	9.45 tracks	9.89 tracks
Level threshold for 16 foils	0.131 grams-TNT	0.114 grams-TNT	0.126 grams-TNT	0.001 grams-TNT

Variance on 32 foils	4.20 tracks
99.9% DL/foil	8.97 $tracks^2$
Level threshold for 32 foils	0.085 grams-TNT
Average background counts	5.587 tracks

Table 3. Oboe 2 Summary.

OBOE 2 SUMMARY

	102 Drift R1 Group	Center of Barrier B1 Group	Right side of barrier C1 Group	Vessel V1 Group
Event Average/foil	5.03 tracks	5.04 tracks	4.71 tracks	4.565 tracks
Variance	4.49 $(tracks)^2$	3.78 $(tracks)^2$	4.67 $(tracks)^2$	4.491 $(tracks)^2$
99.9% DL/foil	9.29 tracks	8.52 tracks	9.48 tracks	9.29 tracks
Level threshold for 16 foils	NA	0.113 grams-TNT	0.125 grams-TNT	7.1E-05 grams-TNT

For all 32 foils on the Oboe Containment barrier we get:

Event Average on 32 foils	4.88 tracks
Variance on 32 foils	4.23 $tracks^2$
99.9% DL/foil	9.01 tracks
Level threshold for 32 foils	0.084 grams-TNT equivalent energy release
Average background counts	5.030 tracks

Table 4. Oboe 3 Summary.

OBOE 3 SUMMARY

	102 Drift R1 Group	Center of Barrier B1 Group	Right side of barrier C1 Group	Vessel V1 Group
Event Average/foil	4.23 tracks	4.95 tracks	4.17 tracks	5.019 tracks
Variance	4.21 $(tracks)^2$	4.41 $(tracks)^2$	4.63 $(tracks)^2$	4.556 $(tracks)^2$
99.9% DL/foil	8.99 tracks	9.20 tracks	9.44 tracks	9.36 tracks
Level threshold for 16 foils	NA	0.132 grams-TNT	0.135 grams-TNT	7.7E-05 grams-TNT

For all 32 foils on the Oboe Containment barrier we get:

Event Average on 32 foils	4.56 tracks
Variance on 32 foils	4.52 $tracks^2$
99.9% DL/foil	9.32 tracks
Level threshold for 32 foils	0.094 grams-TNT equivalent energy release
Average background counts	4.231 tracks

Table 5. Oboe 4 Summary.

OBOE 4 SUMMARY

	102 Drift R1 Group	Center of Barrier B1 Group	Right side of barrier C1 Group	Vessel V1 Group
Event Average/foil	2.58 tracks	2.95 tracks	2.85 tracks	3.231 tracks
Variance	2.58 $(tracks)^2$	3.12 $(tracks)^2$	3.13 $(tracks)^2$	3.031 $(tracks)^2$
99.9% DL/foil	7.04 tracks	7.75 tracks	7.76 tracks	7.63 tracks
Level threshold for 16 foils	NA	0.148 grams-TNT	0.149 grams-TNT	8.4E-05 grams-TNT

For all 32 foils on the Oboe Containment barrier we get:

Event Average on 32 foils	2.90 tracks
Variance on 32 foils	3.13 $tracks^2$
99.9% DL/foil	7.75 tracks
Level threshold for 32 foils	0.105 grams-TNT equivalent energy release
Average background counts	2.583 tracks

Table 6. Oboe 5 Summary.

OBOE 5 SUMMARY

	102 Drift R1 Group	Center of Barrier B1 Group	Right side of barrier C1 Group	Vessel V1 Group
Event Average/foil	3.49 tracks	3.55 tracks	3.56 tracks	4.481 tracks
Variance	4.01 $(tracks)^2$	2.83 $(tracks)^2$	3.75 $(tracks)^2$	3.926 $(tracks)^2$
99.9% DL/foil	8.78 tracks	7.37 tracks	8.49 tracks	8.69 tracks
Level threshold for 16 foils	NA	0.164 grams-TNT	0.188 grams-TNT	1.1E-04 grams-TNT

For all 32 foils on the Oboe Containment barrier we get:

Event Average on 32 foils	3.55 tracks
Variance on 32 foils	3.29 $tracks^2$
99.9% DL/foil	7.95 tracks
Level threshold for 32 foils	0.125 grams-TNT equivalent energy release
Average background counts	3.491 tracks

Table 7. Oboe 6 Summary.

OBOE 6 SUMMARY

	102 Drift R1 Group	Center of Barrier B1 Group	Right side of barrier C1 Group	Vessel V1 Group
Event Average/foil	4.58 tracks	3.75 tracks	5.19 tracks	5.444 tracks
Variance	6.58 $(tracks)^2$	3.89 $(tracks)^2$	4.33 $(tracks)^2$	7.315 $(tracks)^2$
99.9% DL/foil	11.25 tracks	8.65 tracks	9.12 tracks	11.86 tracks
Level threshold for 16 foils	NA	0.158 grams-TNT	0.167 grams-TNT	1.3E-04 grams-TNT

For all 32 foils on the Oboe Containment barrier we get:

Event Average on 32 foils	4.47 tracks
Variance on 32 foils	4.11 $tracks^2$
99.9% DL/foil	8.89 tracks
Level threshold for 32 foils	0.115 grams-TNT equivalent energy release
Average background counts	4.583 tracks

Table 8. Oboe 7 Summary.

OBOE 7 SUMMARY

	102 Drift R1 Group	Center of Barrier B1 Group	Right side of barrier C1 Group	Vessel V1 Group
Event Average/foil	3.56 tracks	3.71 tracks	3.70 tracks	3.565 tracks
Variance	4.04 $(tracks)^2$	3.41 $(tracks)^2$	3.59 $(tracks)^2$	3.069 $(tracks)^2$
99.9% DL/foil	8.81 tracks	8.09 tracks	8.31 tracks	7.68 tracks
Level threshold for 16 foils	NA	0.189 grams-TNT	0.195 grams-TNT	1.0E-04 grams-TNT

For all 32 foils on the Oboe Containment barrier we get:

Event Average on 32 foils	3.71 tracks
Variance on 32 foils	3.50 $tracks^2$
99.9% DL/foil	8.20 tracks
Level threshold for 32 foils	0.136 grams-TNT equivalent energy release
Average background counts	3.565 tracks

Table 9. Oboe 8 Summary.

OBOE 8 SUMMARY

	102 Drift R1 Group	Center of Barrier B1 Group	Right side of barrier C1 Group	Vessel V1 Group
Event Average/foil	5.20 tracks	5.54 tracks	4.76 tracks	4.204 tracks
Variance	4.62 $(\text{tracks})^2$	4.40 $(\text{tracks})^2$	6.70 $(\text{tracks})^2$	5.004 $(\text{tracks})^2$
99.9% DL/foil	9.43 tracks	9.19 tracks	11.34 tracks	9.81 tracks
Level threshold for 16 foils	NA	0.240 grams-TNT	0.296 grams-TNT	1.5E-04 grams-TNT

For all 32 foils on the Oboe Containment barrier we get:

Event Average on 32 foils	5.15 tracks
Variance on 32 foils	5.55 tracks^2
99.9% DL/foil	10.32 tracks
Level threshold for 32 foils	0.191 grams-TNT equivalent energy release
Average background counts	5.204 tracks

Table 10. Oboe 9 Summary.

OBOE 9 SUMMARY

	102 Drift R1 Group	Center of Barrier B1 Group	Right side of barrier C1 Group	Vessel V1 Group
Event Average/foil	1.61 mrem	3.59 mrem	3.67 mrem	3.000 mrem
Variance	10.84 $(\text{mrem})^2$	15.13 $(\text{mrem})^2$	11.41 $(\text{mrem})^2$	16.588 $(\text{mrem})^2$
99.9% DL/foil	14.43 mrem	17.05 mrem	14.81 mrem	17.86 mrem
Level threshold for 16 foils	NA	0.110 grams-TNT	0.095 grams-TNT	0.0001 grams-TNT

For all 32 foils on the Oboe Containment barrier we get:

Event Average on 32 foils	3.63 mrem
Variance on 32 foils	13.27 $(\text{mrem})^2$
99.9% DL/foil	15.97 mrem
Level threshold for 32 foils	0.073 grams-TNT equivalent energy release
Average background dose	1.611 mrem

Table 11. Oboe Dosimeter Summary.

	Oboe 1	Oboe 2	Oboe 3	Oboe 4	Oboe 5	Oboe 6	Oboe 7	Oboe 8	Oboe 9*
Background counts	5.59	5.03	4.23	2.58	3.49	4.58	3.56	5.20	1.61
Barrier counts	4.80	4.88	4.56	2.90	3.55	4.47	3.71	5.15	3.63
99.9% Decision Level	8.97	9.01	9.32	7.75	7.95	8.89	8.20	10.32	15.97
Max Energy release based on DL (mg TNT eq.)	85.00	84.00	94.00	105.00	125.00	115.00	136.00	191.00	73.00
Lid counts	5.93	4.57	5.02	3.23	4.48	5.44	3.57	4.20	3.00
99.9% Decision Level	9.89	9.29	9.36	7.63	8.69	11.86	7.68	9.87	17.86
Max Energy release based on DL (mg TNT eq.)	0.08	0.07	0.08	0.08	0.11	0.13	0.10	0.15	0.10

* On Oboe 9 the units are mrem rather than counts. The effective area read on each dosimeter on Oboe 9 was 1.6 cm^2 rather than .09 cm^2 as the rest of Oboes 1-8.

Scintillator Fission Neutron/Gamma Rate Measurement

To detect neutrons and gammas associated with fission energy release using active methods, we used a Bechtel-Nevada MHD 24-multihead, plastic scintillator detector unit identical to those that were fielded on earlier nuclear safety shots. Indeed, the unit we use for Oboe has been previously used on other SCEs and was assembled for GABBS-Lime, a canceled nuclear test.

The Oboe MHD-24 is a 6.0-inch cube of BC-404 plastic scintillator, viewed by three photomultipliers (BN Type PMH-5) and a photodiode (BN Type PDH-4) mounted on four faces of the cube. The detector was mounted in an EMI shielded aluminum box and placed in a space in the I-beam lattice of the outer containment barrier, just below and to the right of the crawl tube as shown in Fig. 2. Jumper cables to the detector heads are made with double-shielded, RF-214 cable, with identical cable, EMI shielding practice, as on previous safety shots.

In order to verify that all diagnostic equipment, including the detector itself, is active and working at event time, several things are done:

1. The voltages of each PM and PD tube are monitored continuously.

2. A zero-time signal, triggered from the shot detonator unit, is placed near the start of each digitizer record.

3. A small LED is placed on the detector assembly, and this unit is triggered about 125 μs after the shot detonator. In this way, we can verify system integrity for the recording time of interest. Simple shock physics dictates that a nuclear signal would occur between detonator firing and 100 μs.

These data are recorded by DTRA and their contractor, Allied Signal, in the "horseshoe alcove" of the U1a tunnel complex. The sensitivity and *in situ* sensitivity of each element of the detector head is shown in Table 12 below. This is shown graphically in Fig. 4.

Table 12. Active Detector Summary.

PM-1 MHD-24/PMH-5	
γ-Sensitivity @ Co^{60}	3.00E-13 coul/γ-MeV
n-Sensitivity (@ 14.1 MeV)	1.15E-12 coul/n
Total signal (gamma + neutron)	8.07E-05 coul/g (TNT)
PM-2 MHD-24/PMH-5	
γ-Sensitivity @ Co^{60}	1.00E-14 coul/γ-MeV
n-Sensitivity (@ 14.1 MeV)	3.85E-14 coul/n
Total signal (gamma + neutron)	2.69E-06 coul/g (TNT)
PM-3 MHD-24/PMH-5	
γ-Sensitivity @ Co^{60}	1.30E-16 coul/γ-MeV
n-Sensitivity (@ 14.1 MeV)	5.00E-16 coul/n
Total signal (gamma + neutron)	3.50E-08 coul/g (TNT)
PD-1 MHD-24/PDH-4	
γ-Sensitivity @ Co^{60}	3.00E-18 coul/γ-MeV
n-Sensitivity (@ 14.1 MeV)	1.15E-17 coul/n
Total signal (gamma + neutron)	8.07E-10 coul/g (TNT)

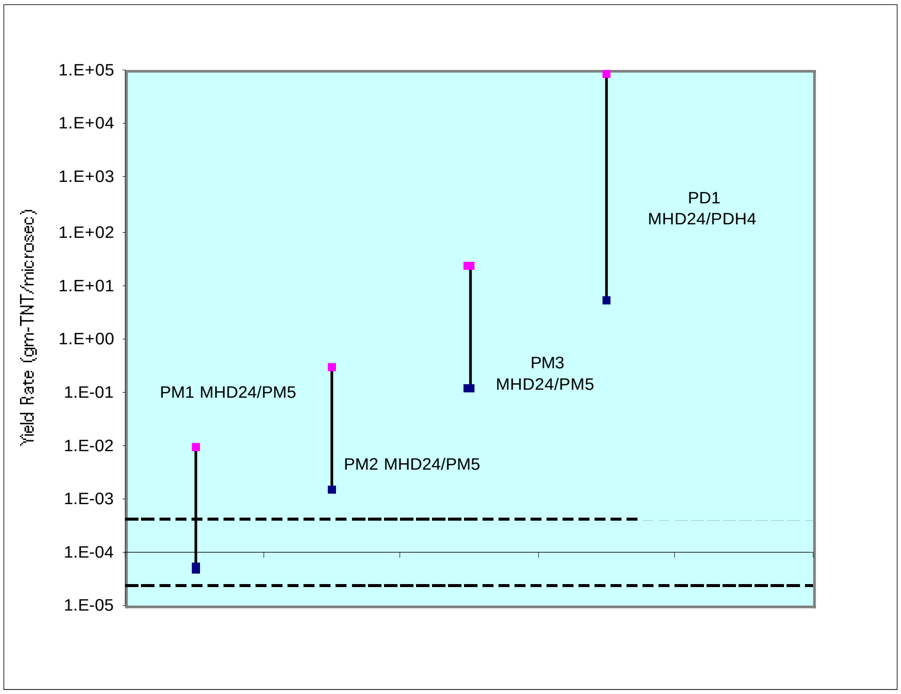

Fig. 4 . Transparency Detector Coverage. The dashed lines indicate uncertainties in computing the detector coverage.

We have no good way to calibrate the detectors for sensitivity to neutrons. They are calibrated using gamma rays on the BN Co^{60} source, and then the data in the reference[iv] is used to derive the neutron sensitivity using the published ratios.

The results from the two active PM tube measurements are shown in Figures 5-13. The first pulse on each record is the "det shaper," which is derived from the fire signal. The second pulse on Oboe 2 and 8 (at about 20 microseconds) is the signal from the radiography x-ray tube. The third pulse (second on Oboe 1 and 3-9) (at about 120 µs) is a small test light pulsar (LED) on the scintillator crystal to provide a positive indication that the photomultiplier tubes and recording system are working properly. For comparison, the Final Dry Run signal is shown on each plot, offset by –0.3 volts. Fig. 14 shows the electronic "one-line" of the Oboe Transparency system.

The green line is the expected voltage that a 0.1 mg nuclear "explosion," 1 µs in duration, would produce. Notice that no signals are observed that could possibly be interpreted as a nuclear signal.

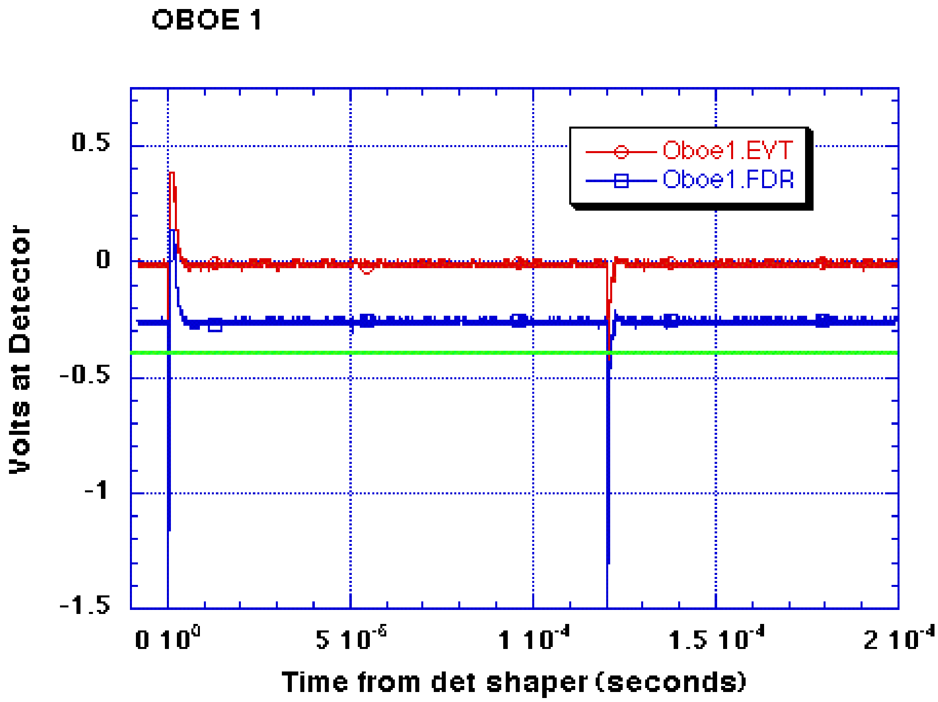

Fig. 5. **Oboe 1 Active Detector Results.**

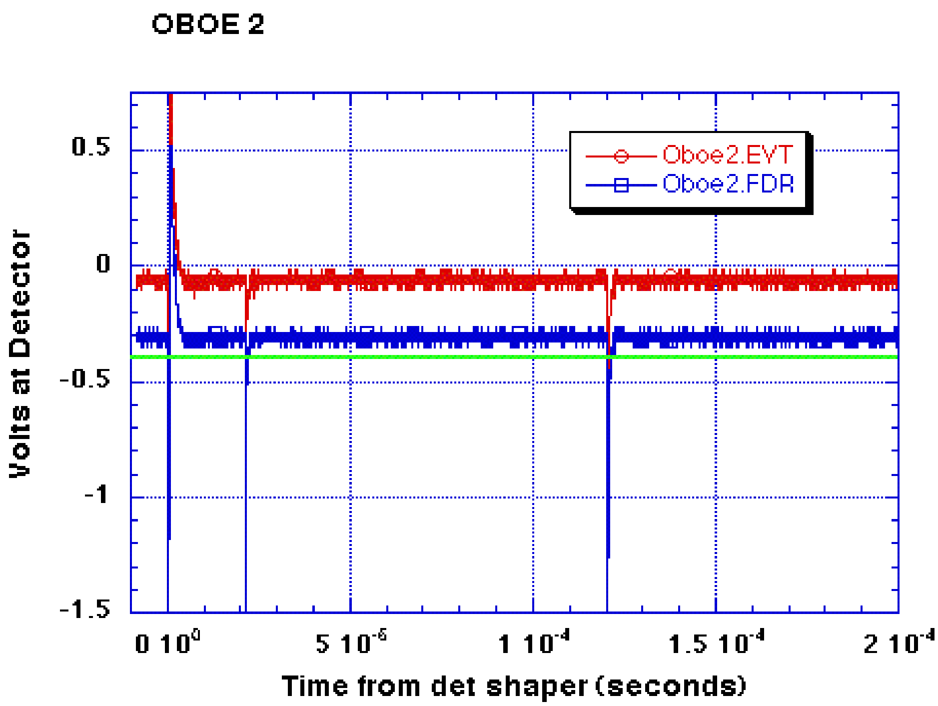

Fig. 6. **Oboe 2 Active Detector Results.**

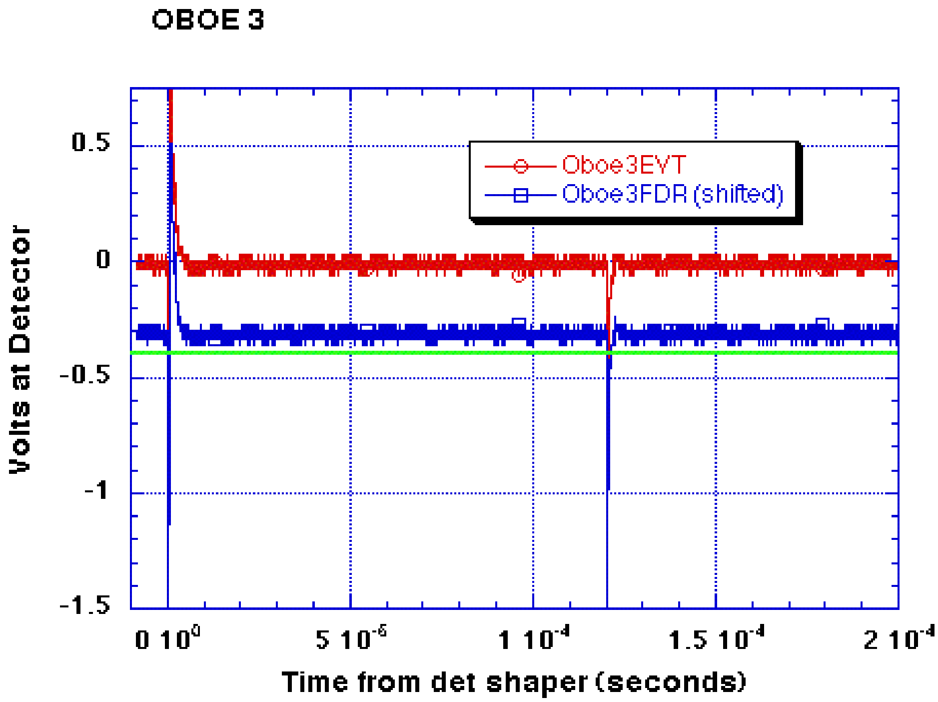

Fig. 7. Oboe 3 Active Detector Results.

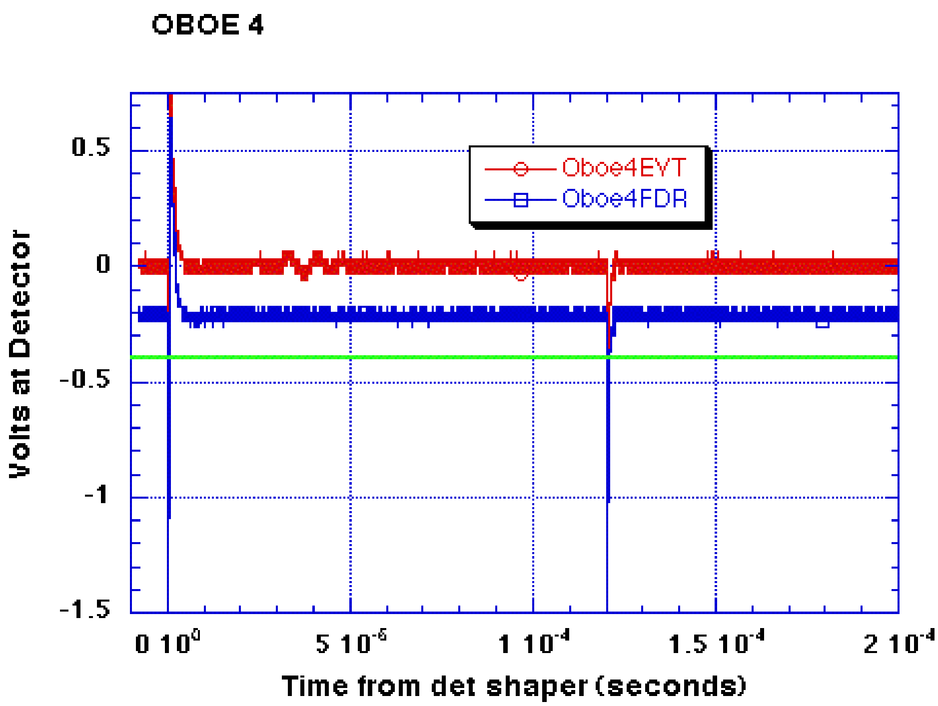

Fig. 8. Oboe 4 Active Detector Results.

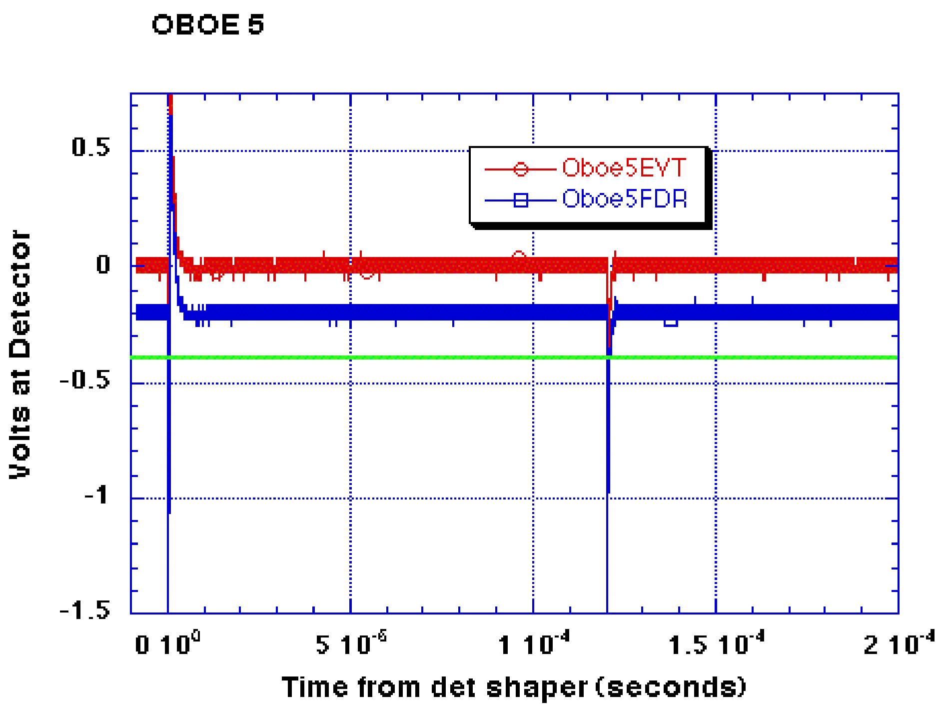

Fig. 9. Oboe 5 Active Detector Results.

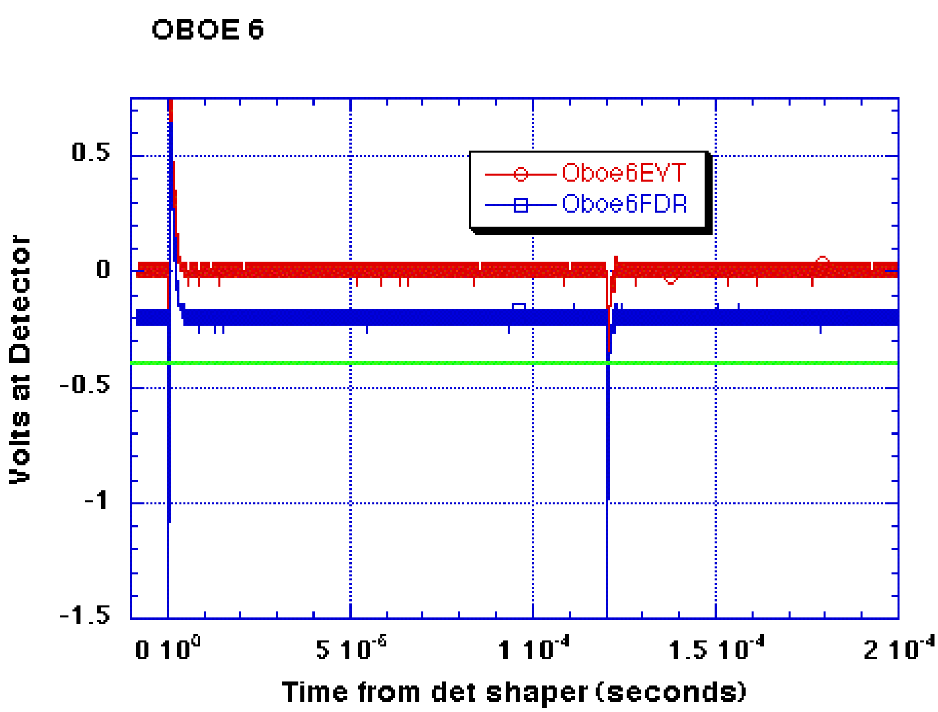

Fig. 10. Oboe 6 Active Detector Results.

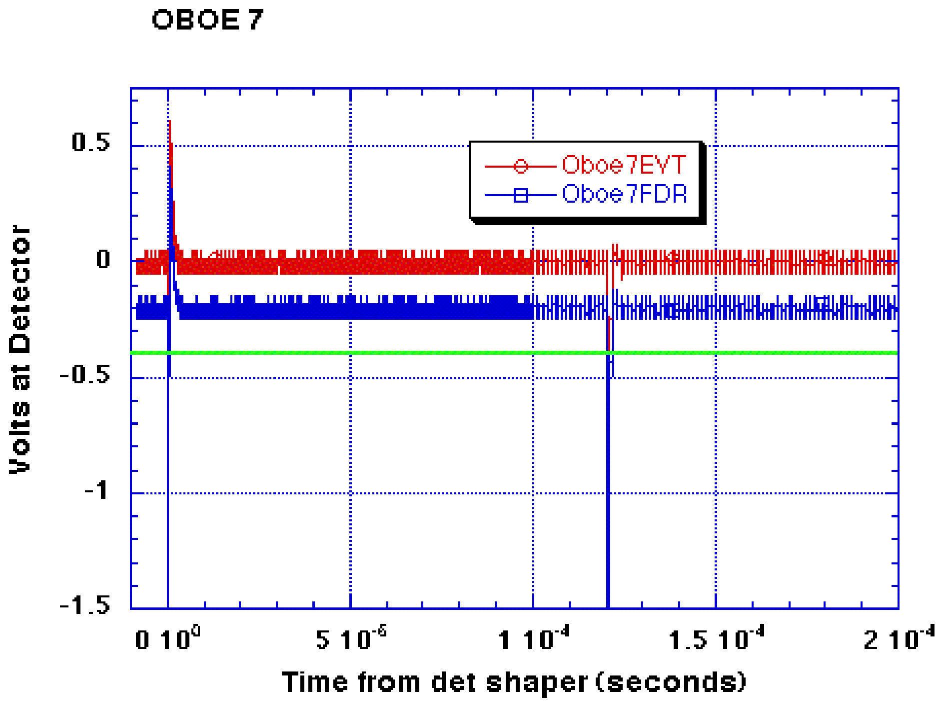

Fig. 11. Oboe 7 Active Detector Results.

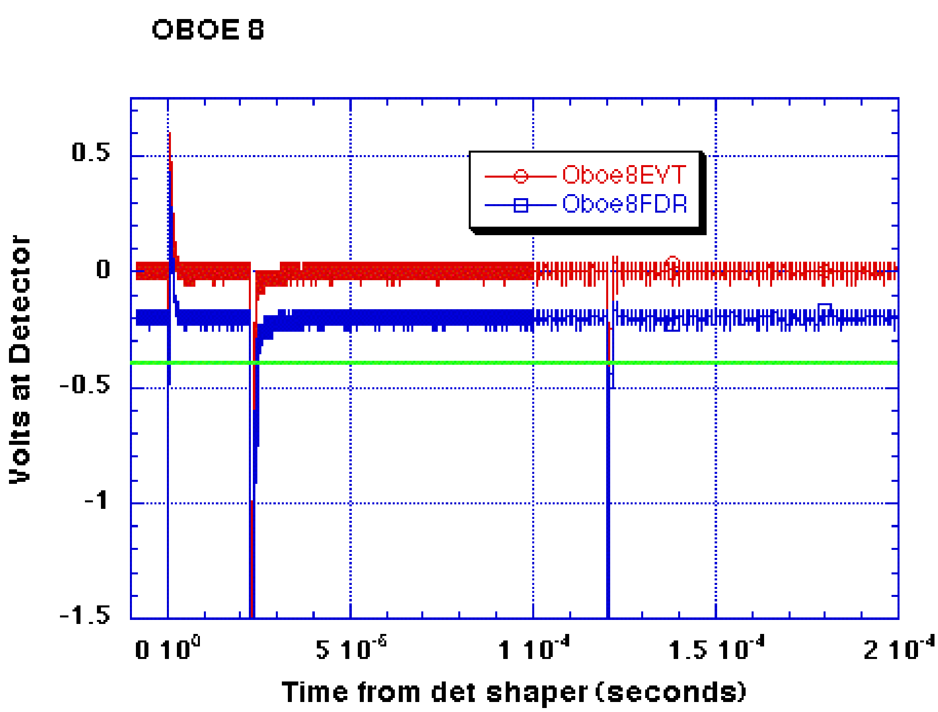

Fig. 12. Oboe 8 Active Detector Results.

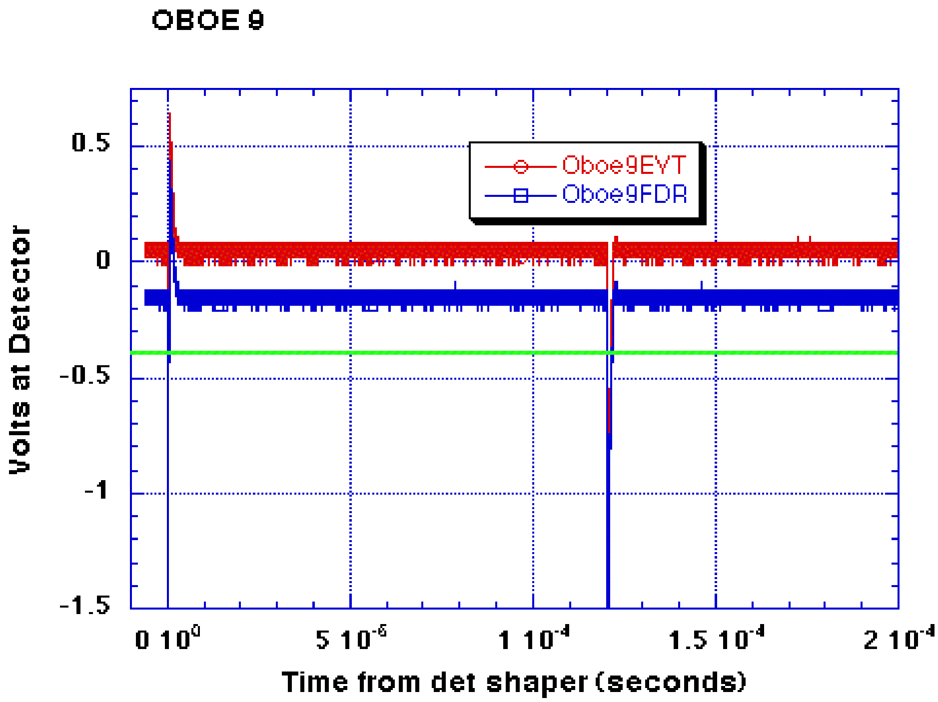

Fig. 13. Oboe 9 Active Detector Results.

Error Budget

We show below an estimate of the error budget with the major contributors to measurement uncertainties.

Neutron per fission uncertainty	1.6
Solid angle uncertainty	1.6
Barrier transmission	1.15
Detector response	1.2
Total (from adding in quadrature)	1.9

Verification Summary

We have made every effort to make the “Transparency” measurements resistant to spoofing (cheating).

1. The dosimeters are processed “blind,” and there are multiple dosimeters.

2. A zero-time fiducial and a light pulse are inserted on each active detector line, thus, establishing that the detector was “alive” during the time at which the SCE was performed.

3. The voltages on the active detectors are monitored continuously before, during, and after the performance of the SCE, thus, assuring that the transducers were not somehow powered down.

4. The set-up checklist from each SCE is maintained as part of the permanent record of each experiment.

In spite of these precautions, spoofing might still be possible. To perform a more positive verification that we have not been exceeding criticality on LLNL SCEs, a third-party verifying organization and much more physical scrutiny of the measurement system would be required.

Conclusion

For each of Oboe 1-9 we saw no evidence of nuclear energy release above the 0.1 mg threshold, which we established before Oboe. Indeed we saw no sign of any nuclear energy release from any of the dosimeter arrays or the active scintillation detector.

Acknowledgement

Thanks to Mr. Jack Janne of Bechtel-Nevada for his work in the care and feeding of the active detector package in the Transparency Measurement. Thanks also to the DTRA recording crew: Howard Ross, Mick Coburn, and Jim Tate, et al., for their (almost thankless) job of recording the electronic data on each Oboe. Also, thanks to Ms. Maria Alvarado of Bechtel-Nevada for her work in preparing each neutron dosimeter and her care in processing and analyzing the dosimeter data.

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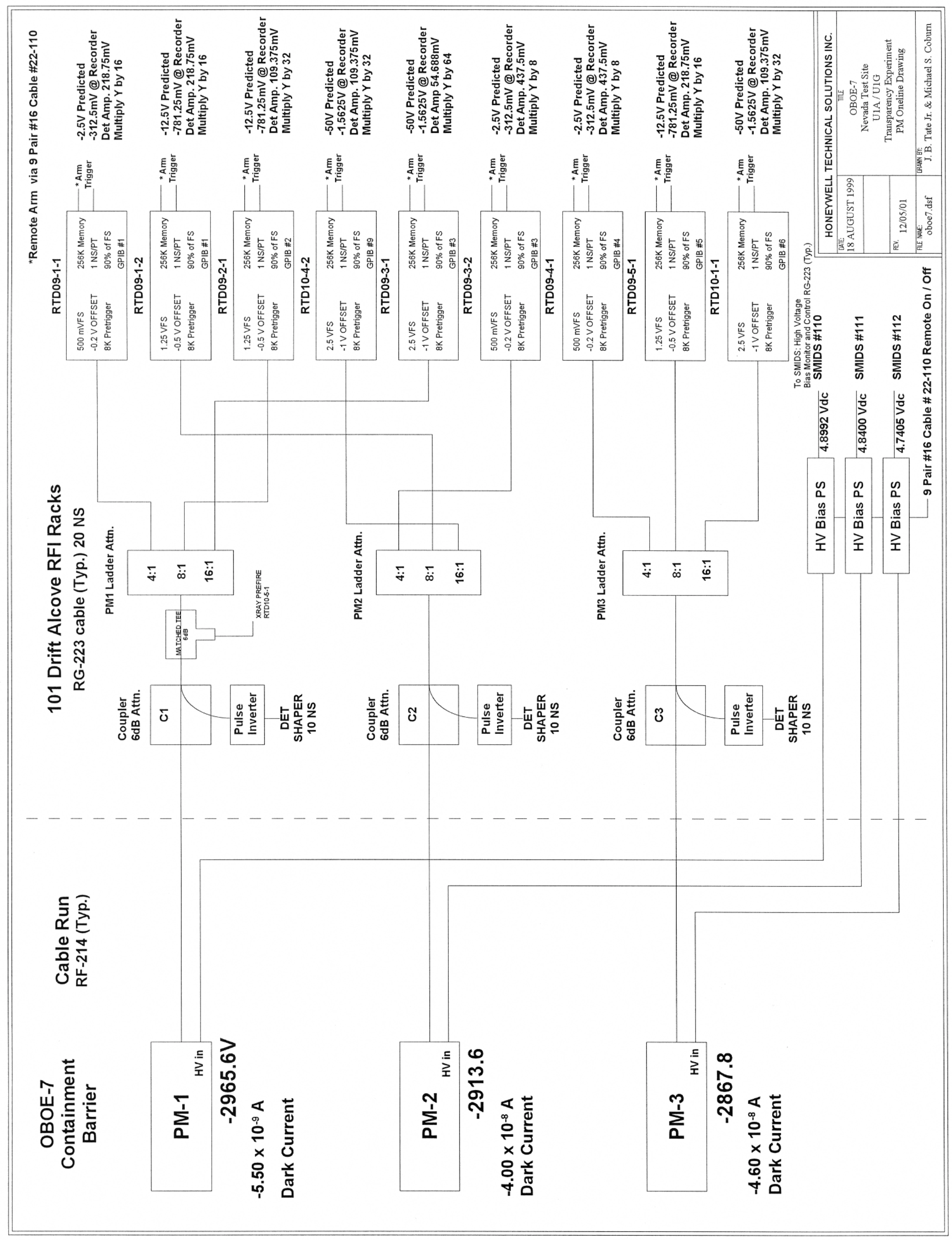

Fig. 14. Oboe Transparency One-Line.

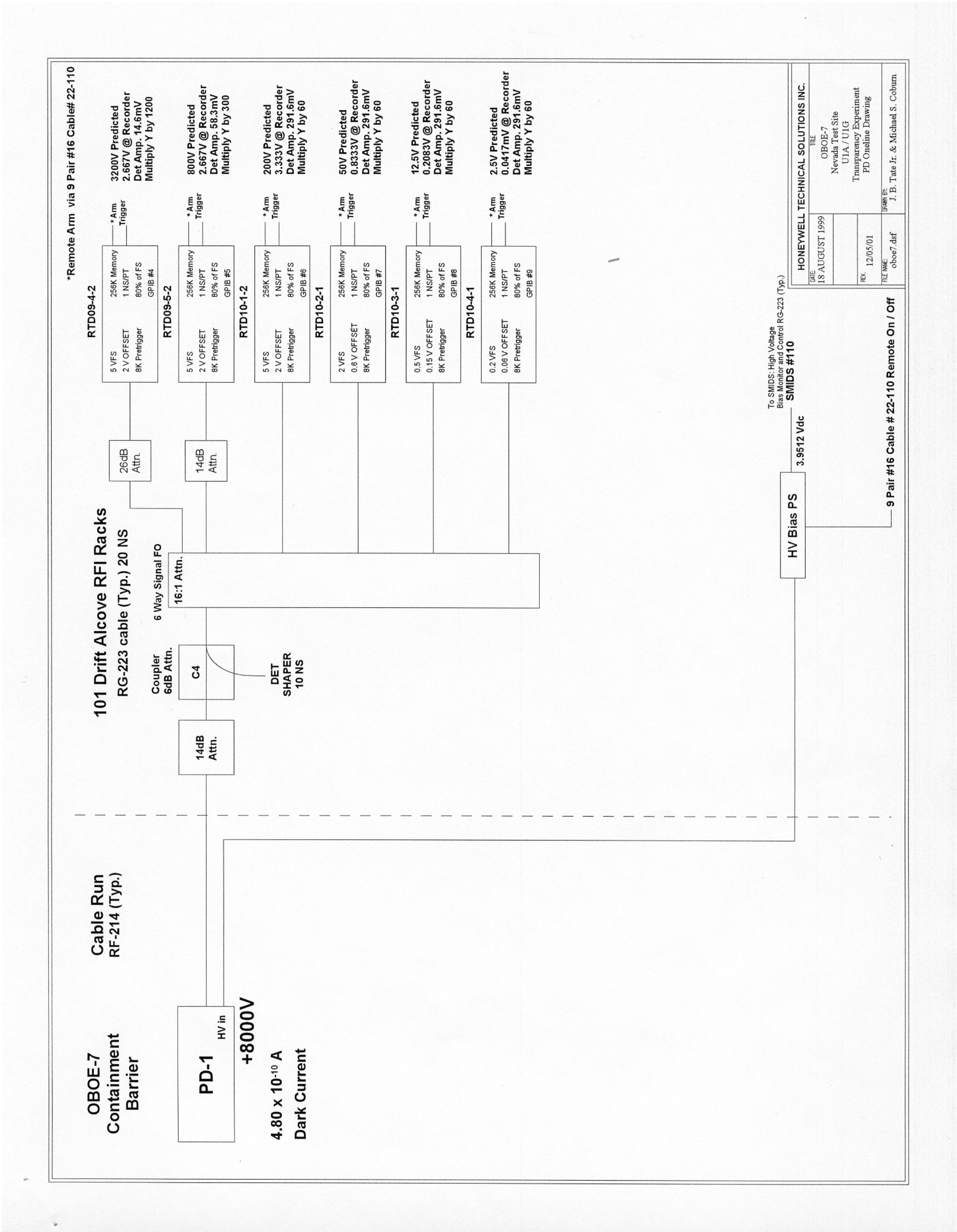

Fig. 14. Continued Oboe Transparency One-line.

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